Occult Injuries to Side NCAP Occupants

CIREN December 2002

Froedtert Hospital – Medical College of Wisconsin CIREN Center

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Dept of Neurosurgery
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Purpose

- To determine crash circumstances that produce head injuries in lateral crashes
- To compare NCAP data with NASS and crash experience
- To determine the variability of NCAP tests especially with head injuries

Gennarelli et al IRCOBI 2002;
Yoganandan et al IRCOBI 2002

Methods

NASS: National Automotive Sampling System

- Years 1993-2000 (AIS 90)
- HI defined as head AIS > 0
- Exclude scalp, external injuries
- MAIS used if more than one HI
- Near side occupants > 16 year old where restraint use known
- “Unbelted” includes with or without airbag

Methods
NASS

- “Belted” includes with or without airbag
- Front and rear passengers included
- Exclude ejections, rollovers
- Delta-V’s collapsed into 10 km/h categories

Methods

NASS – Clock nomenclature

PDOF	Driver (left) side	Right Side
Frontward	10	2
Direct Side	9	3
Rearward	8	4

Methods

NCAP: New Car Assessment Program

- Side NCAP since 1997
- Patterned after FMVSS 214 + 5mph
- 1361 kg moving deformable barrier crabbed at 27° strikes stationery vehicle at 38.5 mph (64kph) on driver side door (approximates 10 o'clock PDOF)
- Simulates striking vehicle at 34mph (57kph) into struck vehicle moving 17mph (28kph)
- Delta V's range 18-25mph (30-42kph) depending on vehicle weight

Methods
NCAP

- SID dummy (head-neck = Hybrid II; now Hybrid III)
- pelvis, spine (T12), two rib accelerometers
- One head tri-ax for HIC
- “Star” safety rating (1 to 5) depends only on spine and rib measures, the
- TTI = $0.5*(a_{spine} + a_{ribmax})$
- 145 dummies in 77 crashes used
- Data from our own MCW NCAP used

NASS Results

Because of large numbers all differences
> 0.05% are significant @ $p < 0.05$

Incidence of HI in Side Impact

NASS 1993-2000

- 1,296,366 Occupants
- 88,074 head injured
- 6.8% Head Injured

Incidence of HI in Side Impact

NASS 1993-2000

Percent HI by Direction

	AIS=0	AIS>0	TOTAL	% HI
frontward	667,237	53,179	720,416	7.4%
direct side	461,570	29,807	491,377	6.1%
rearward	79,455	5,088	84,543	6.0%
total	1,208,262	88,074	1,296,336	6.8%

- The chances of incurring HI were equal in all three directions

Incidence of HI in Side Impact

NASS 1993-2000

Percent of Entire Series

Direction	n	AIS=0	AIS>0	TOTAL
frontward	720,416	51.5%	4.1%	55.6%
direct side	491,377	35.6%	2.3%	37.9%
rearward	84,543	6.1%	0.4%	6.5%
total	1,296,336	93.2%	6.8%	100.0%

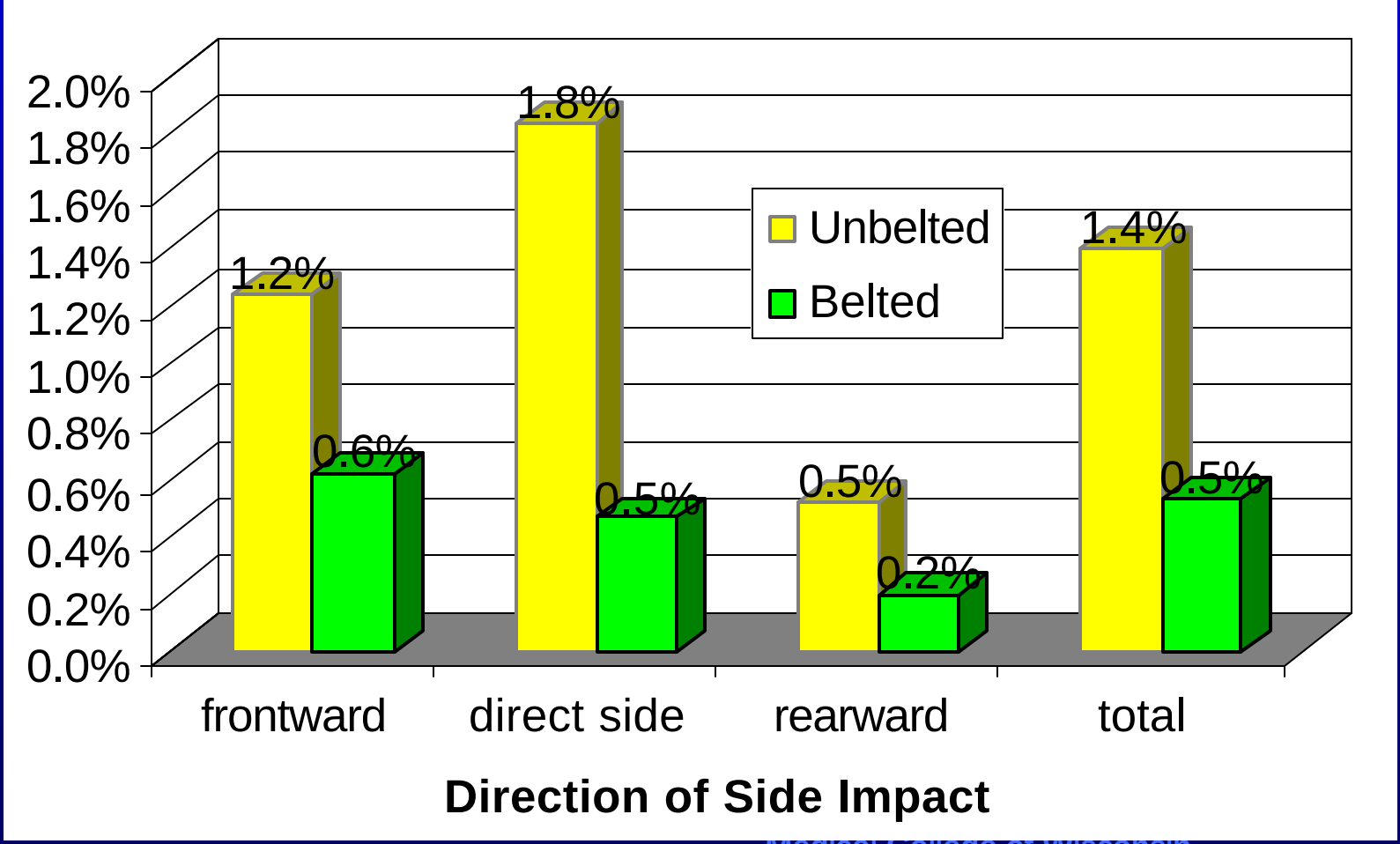
- However, frontward crashes were most frequent
- Thus, most HI occurred in frontward crashes

Severity of HI
All Occupants

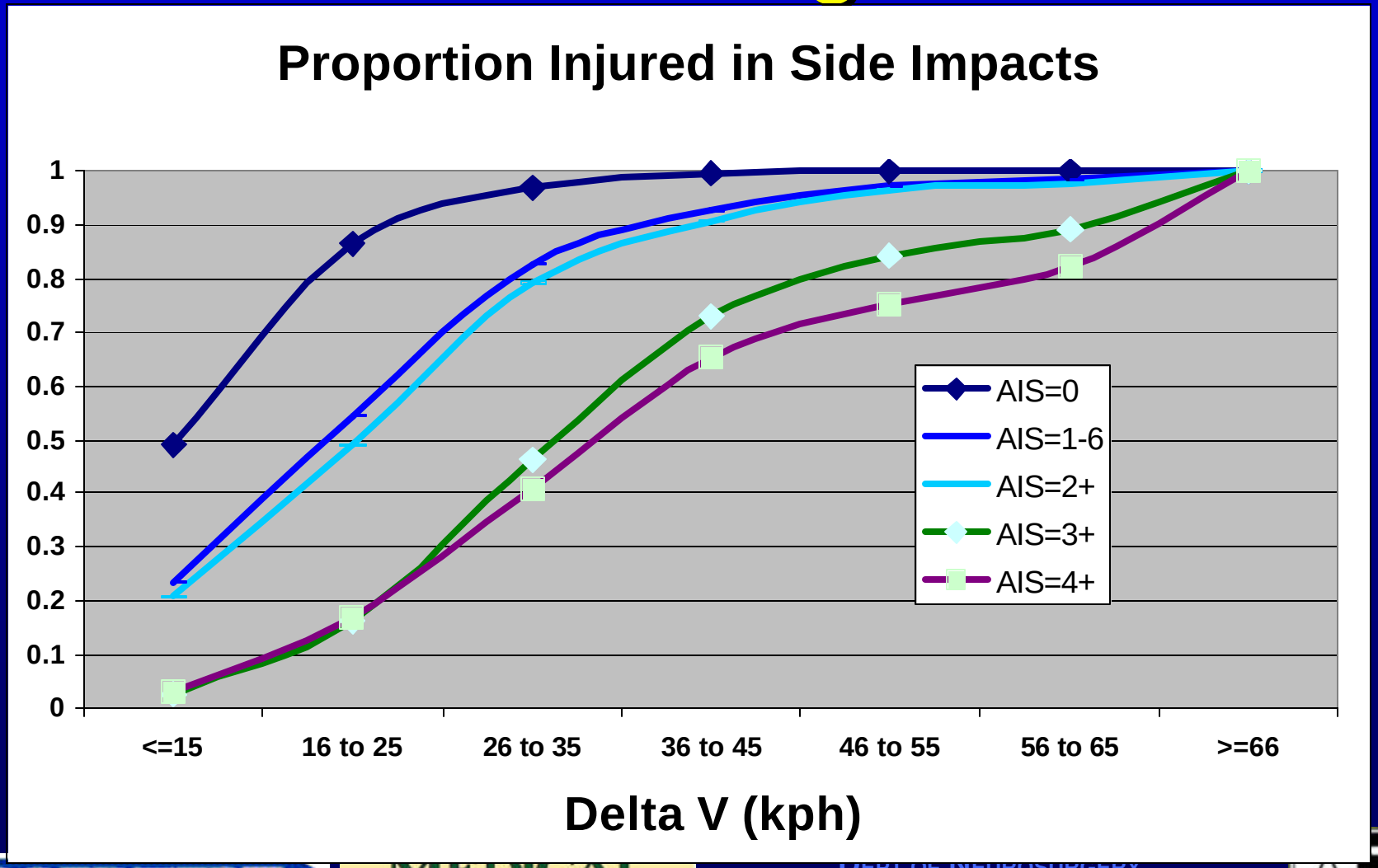
	AIS 1-2	AIS 3+	Total	percent AIS 3+
frontward	44,552	8,627	53,179	16.2%
direct side	23,764	6,043	29,807	20.3%
rearward	4,423	665	5,088	13.1%
total	72,739	15,335	88,074	17.4%

- More Serious HI occurred in frontward crashes because there were so many of them
- But, direct side crashes had higher risk of serious HI

Risk of AIS 4+ Head Injury in Side Impacts



Cumulative Probability of Sustaining HI



NCAP Results

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CIREN Case
Crash of
1999 Isuzu Hombre
and
1995 Chevrolet Camaro

Mimics a Side NCAP Test

Department of Neurosurgery
Medical College of Wisconsin
and VA Medical Center

NCAP ‘Star Ratings’ of 2000 Isuzu Hombre (Sister of 1999 Isuzu Hombre)

- 3 star frontal rating for both driver and passenger
- 4 star side impact rating for front passenger
- Side impact: TTI =69g; pelvis = 77g

Case Occupant - 1999 Isuzu Hombre

- Driver
- 56-year-old male
- 173 cm (5’ 7.5 ”), 111kg (245 lb)
- 3-point belt worn
- Driver airbag non-deployed

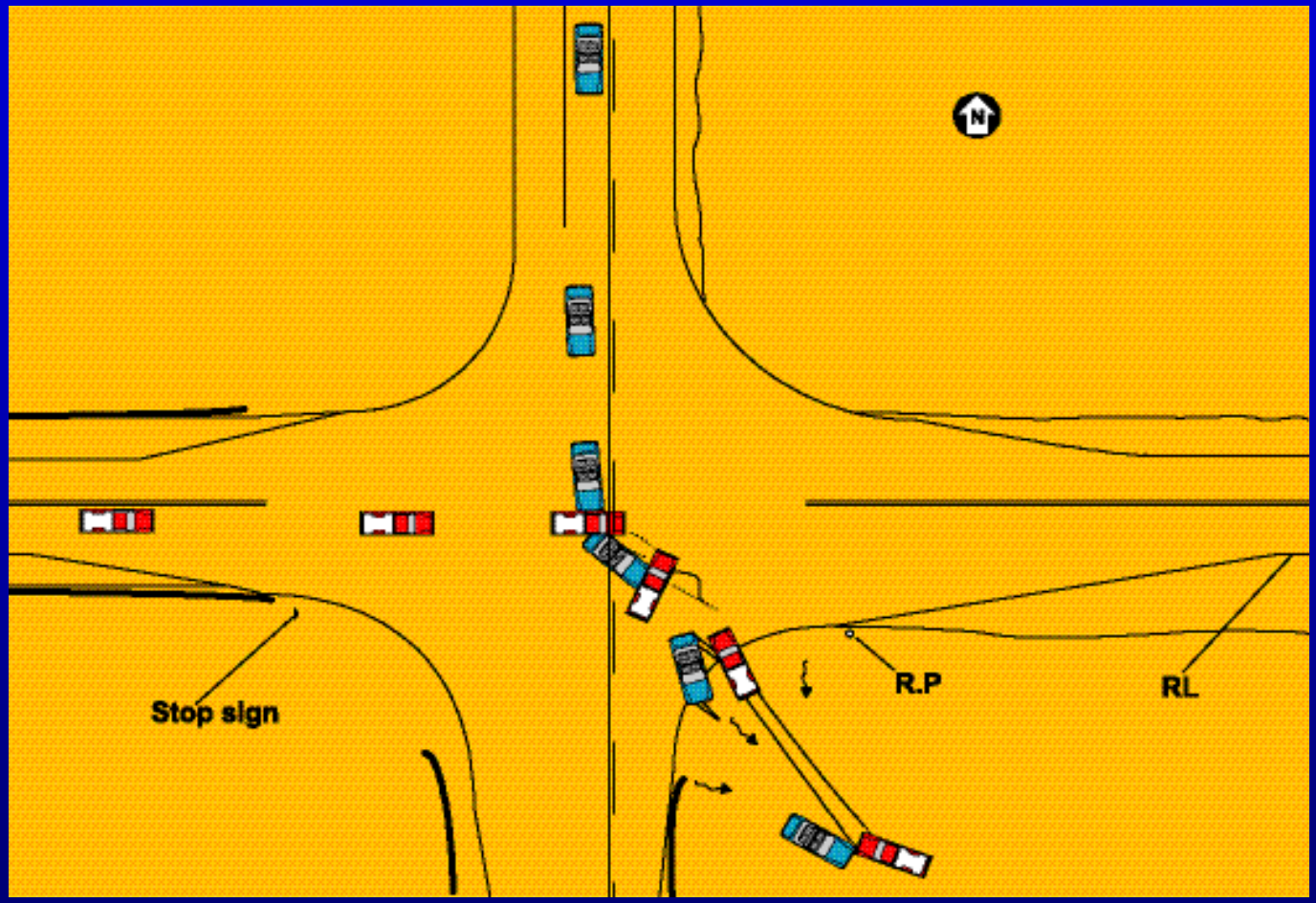
Case Occupant Injuries

Case Occupant:	**Major Injuries:**		
Position: Driver	Body Region	Injury	AIS
Age/Gender: 55-year-old male Stature/Mass: 172 cm (5' 7.5"), 111 kg (245 lb) Restraint: ✹ 3-point belt worn, ✹ near side impact, ✹ airbag not deployed MAIS: 4 ISS: 36 PDOF: 10 o'clock Delta V = 21 mph	Head Abdomen Thorax	Loss of consciousness, <10 minutes Laceration, major left kidney Contusion, bilateral lungs w/ left hemo-pneumothorax	2 4 4

Case Occupant Outcome

- Left nephrectomy
- Weight bearing on right at discharge
- Toe-touch weight bearing on left
- Rehabilitating at parents' home out of state
- Separated from wife

Crash Overview

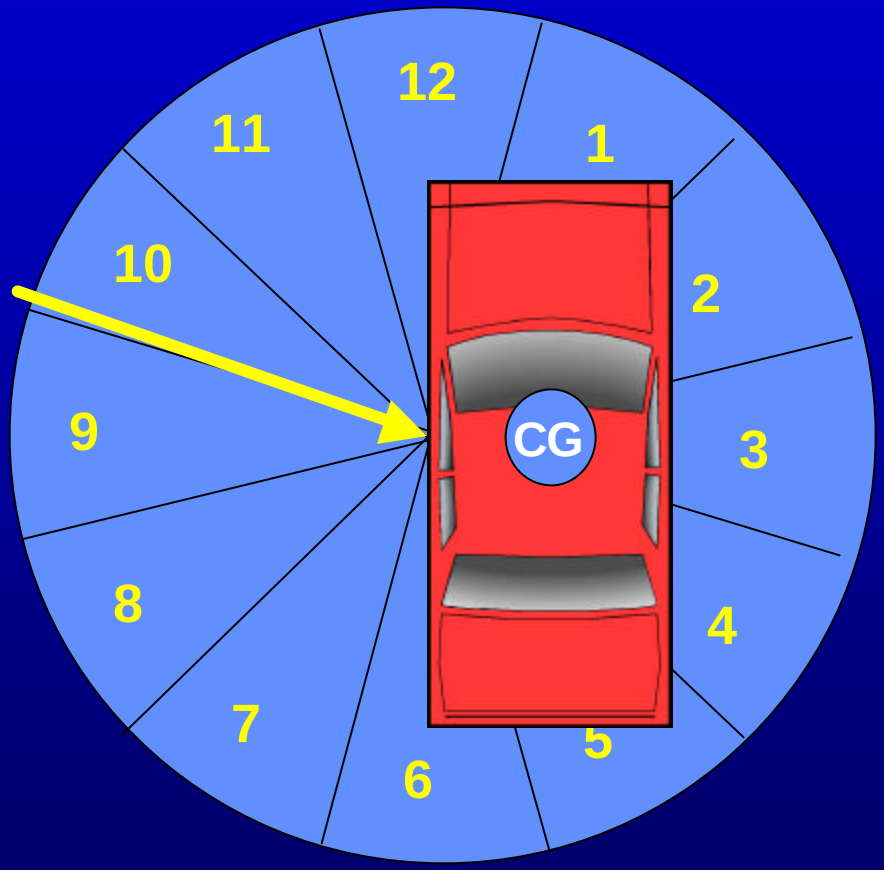


The case vehicle entered a four-leg intersection and crossed the path of vehicle two. Vehicle two struck the case vehicle broadside. Both vehicles entered a counterclockwise rotation, departed the roadway off of the southeast corner and traveled down an embankment before they came to rest.

Path of Case Vehicle

Path of Case Vehicle

10 o'clock PDOF
CDC 90-LZEW-4



Delta V (Roldmiss)
= 21 mph

1999 Isuzu Hombre

Exemplar Vehicle
(Undamaged)

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Driver' side (door panel removed) showing 49cm of maximum crush

Comparison of 1999 Isuzu Hombre (post crash) to exemplar Chevy S-10 (undamaged)

1999 Isuzu Hombre

Exemplar Chevy S-10
(Hombre Clone)

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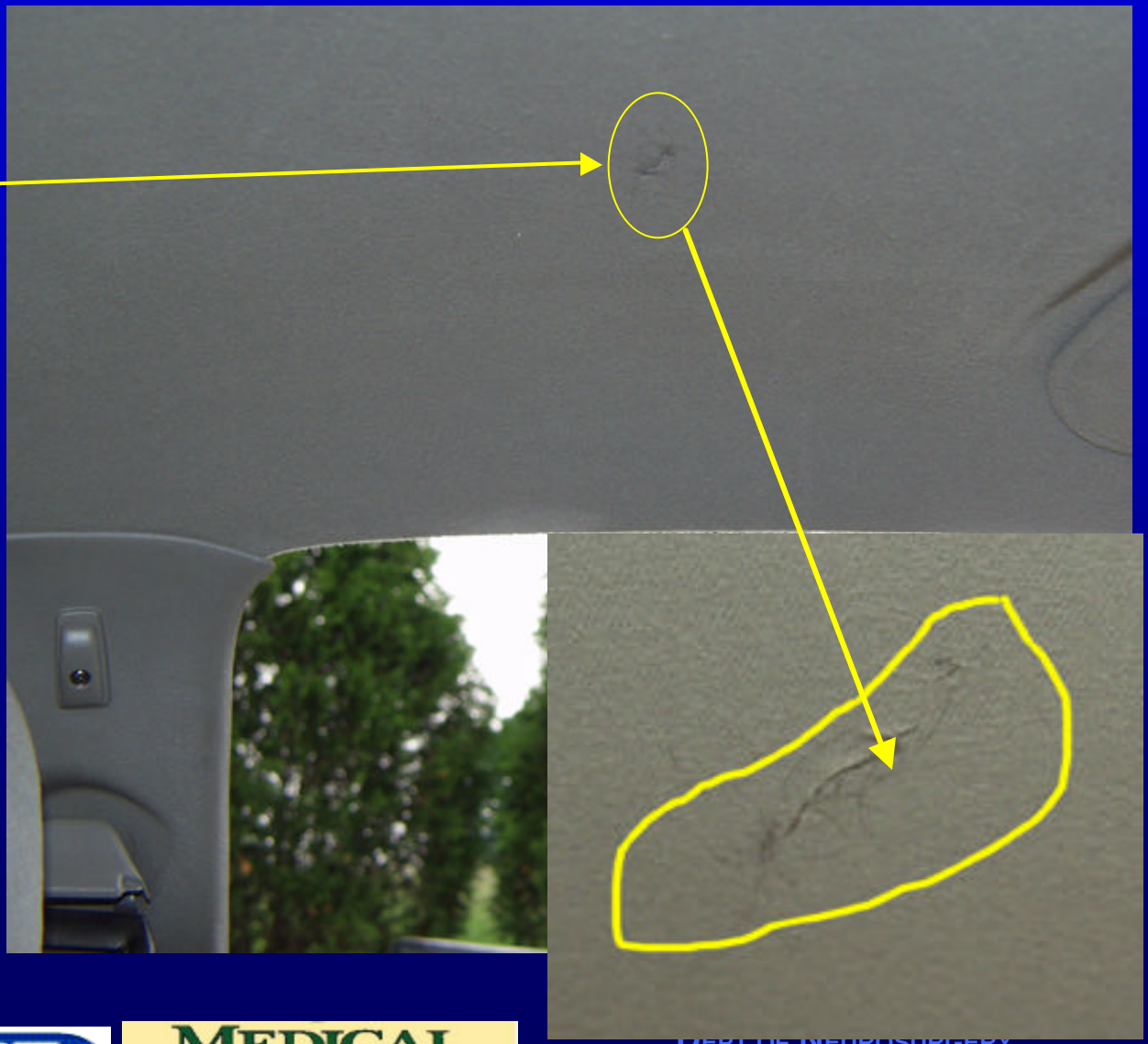
Driver Seat - 1999 Isuzu Hombre

Estimated 27 cm of left door intrusion

Interior photo showing torn headliner and hair deposit

Headliner torn and hair deposit



Left B-pillar - 1999 Isuzu Hombre

Left B-pillar scuff mark with fiber transfers

Armrest - 1999 Isuzu Hombre

Injuries

predominantly left sided

Injury	AIS
Abrasion, left parietal scalp	1
Contusion, left parietal scalp	1
Loss of consciousness, < 10 minutes	2
Contusion, bilateral lungs w/ left hemo-pneumothorax	4
Fracture, left posterior T-12 rib	1
Contusion, left adrenal gland (4 x 3 cm)	1
Contusion, minor right kidney (subcapsular hematoma)	2
Laceration, major left kidney	4
Laceration, minor spleen (left)	2
Laceration, small bowel mesentery	2
Fracture, left pubis and pubic ramus	2
Contusion, left shoulder	1

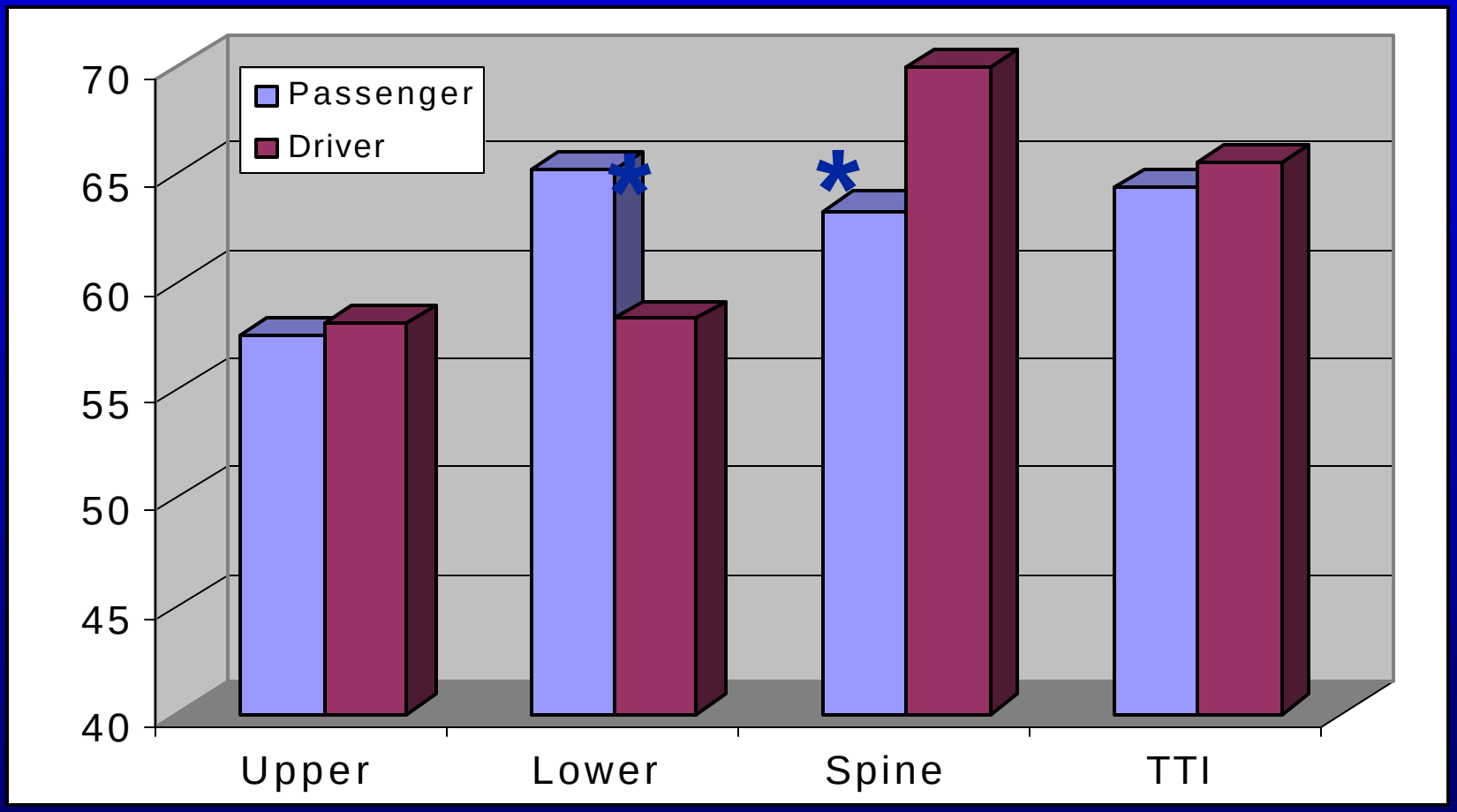
This is a 4 Star safety vehicle???

What are some reasons for injuries to NCAP occupants?

- Variability in driver and passenger responses
- Poor relation between the injury criteria (TTI) and other injury tolerances (HIC)
- Many injuries not measured or accounted for (neck, abdomen, pelvis)
- High injury acceptance rate

Rib (upper/lower) and T12 accelerations (g)

n = 77 side NCAP tests



- Passenger lower rib and spine acceleration responses differ from the driver

* ± p<0.001

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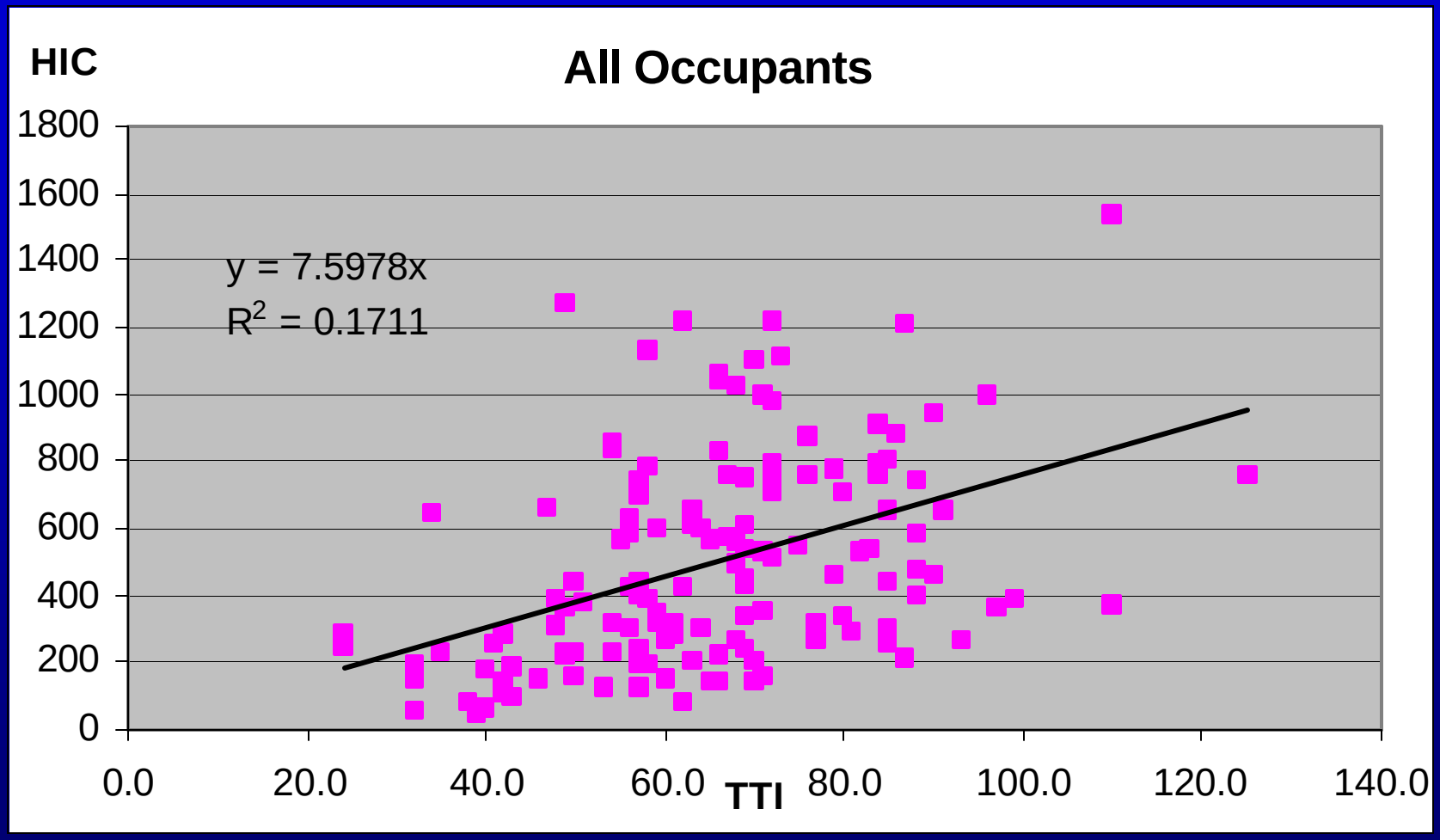
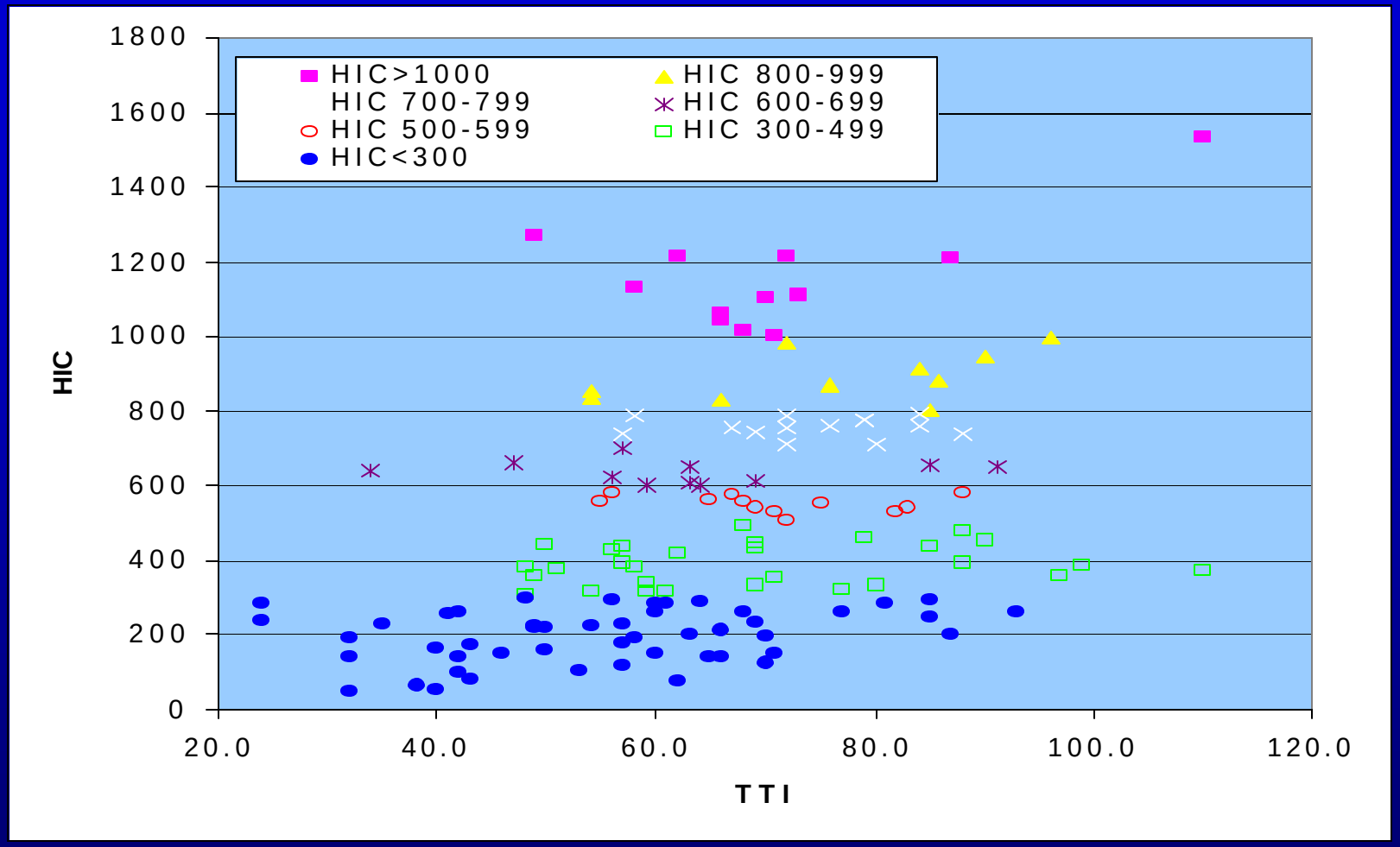
HIC and TTI correlate poorly



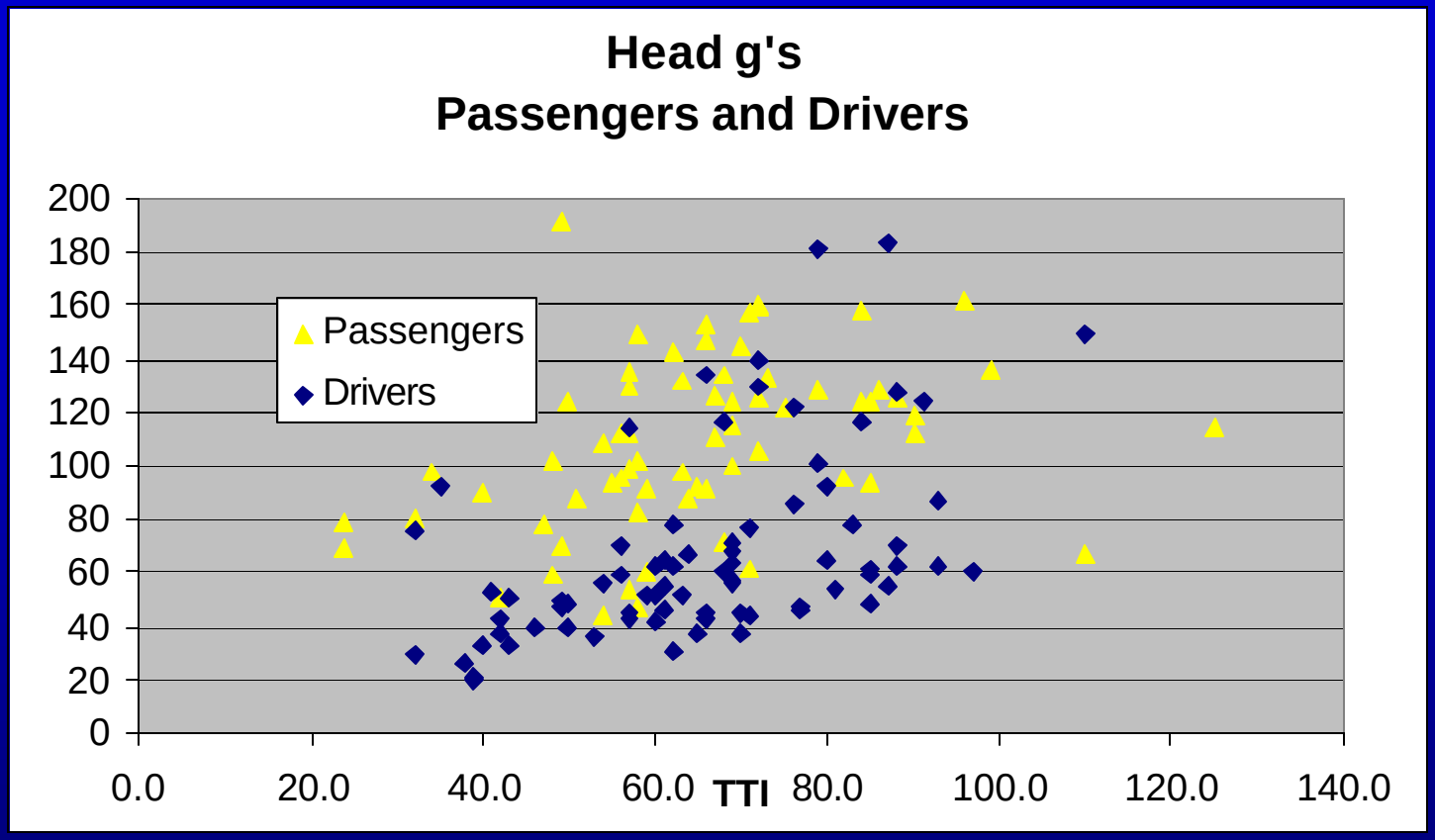
- Thus, TTI cannot be a surrogate measure of whether HI will occur

HIC and TTI



- Lack of correlation between TTI and HIC occurs at all HIC levels

NCAP Results: Head g's



- Rear passengers have higher head accelerations than drivers
- Note poor correlation between g's and TTI

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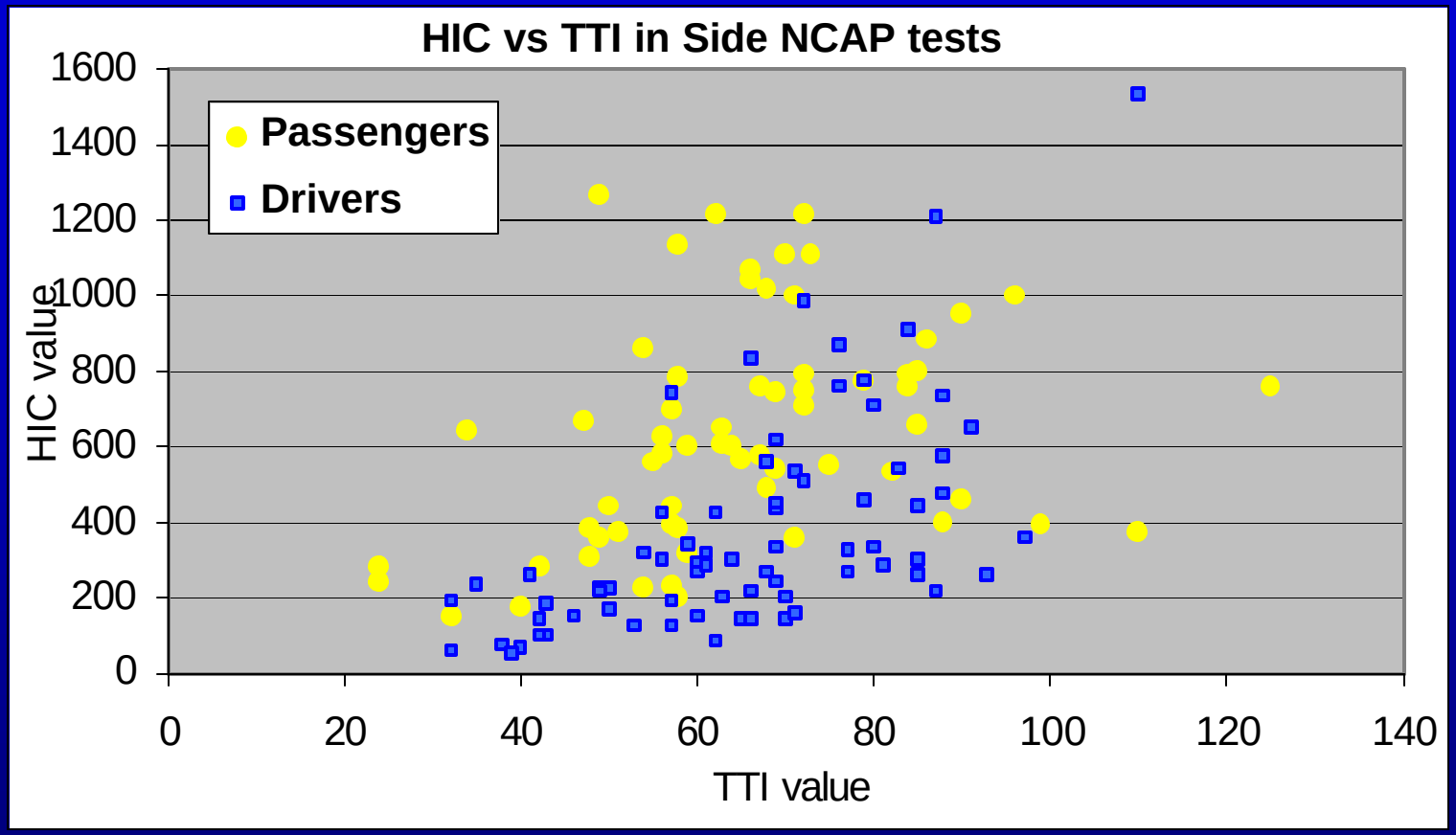
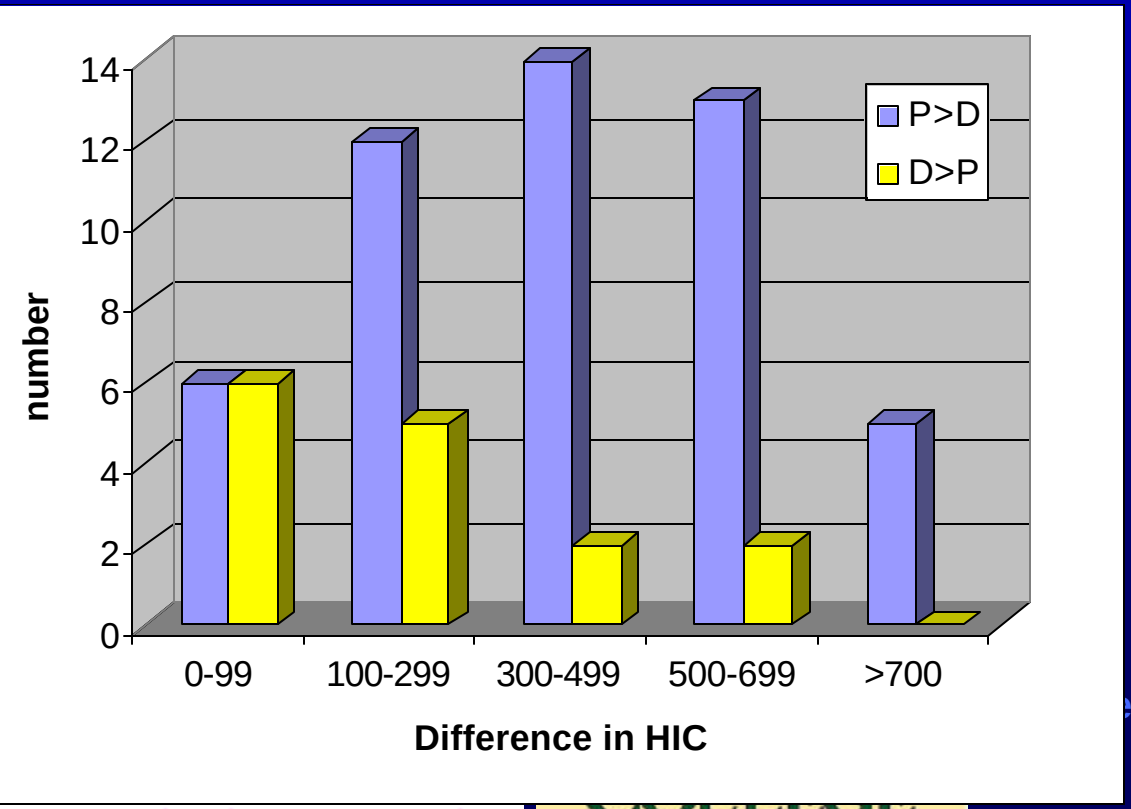
NCAP results: HIC



- HIC was much higher for rear passengers
- Note poor correlation of HIC and TTI
- r^2 = 0.61 driver; = 0.33 passenger

NCAP driver vs. passenger HIC

- 65 crashes with driver (D) and passenger (P) HIC data
- 50/65 (77%) passenger HIC higher
- 15/65 (23%) driver higher
- Passenger Mean HIC x2 driver with same TTI



Mean Value	Driver	Pass
HIC	374	635
TTI	66	65

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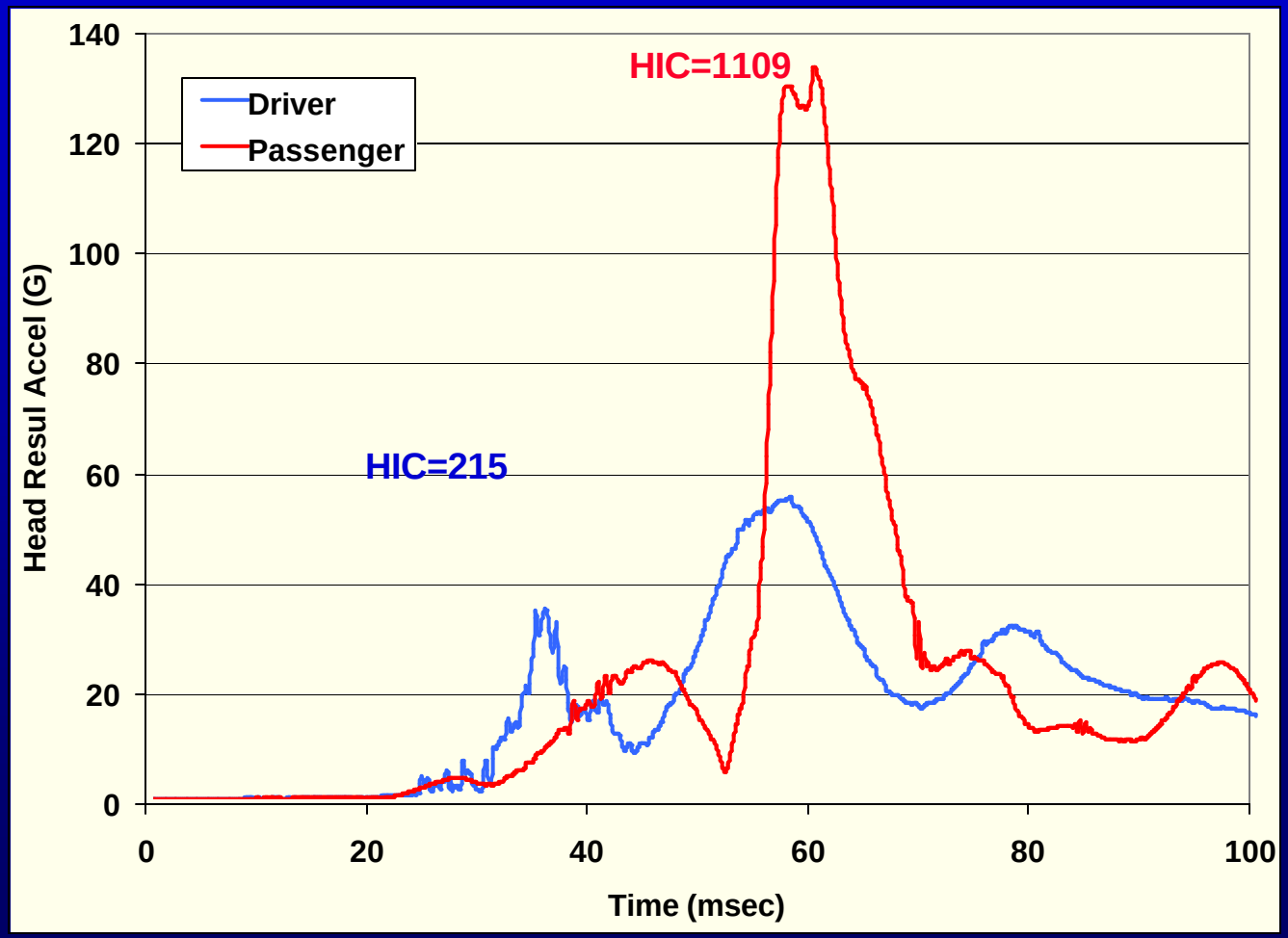
2001 Buick Century
Side NCAP Test



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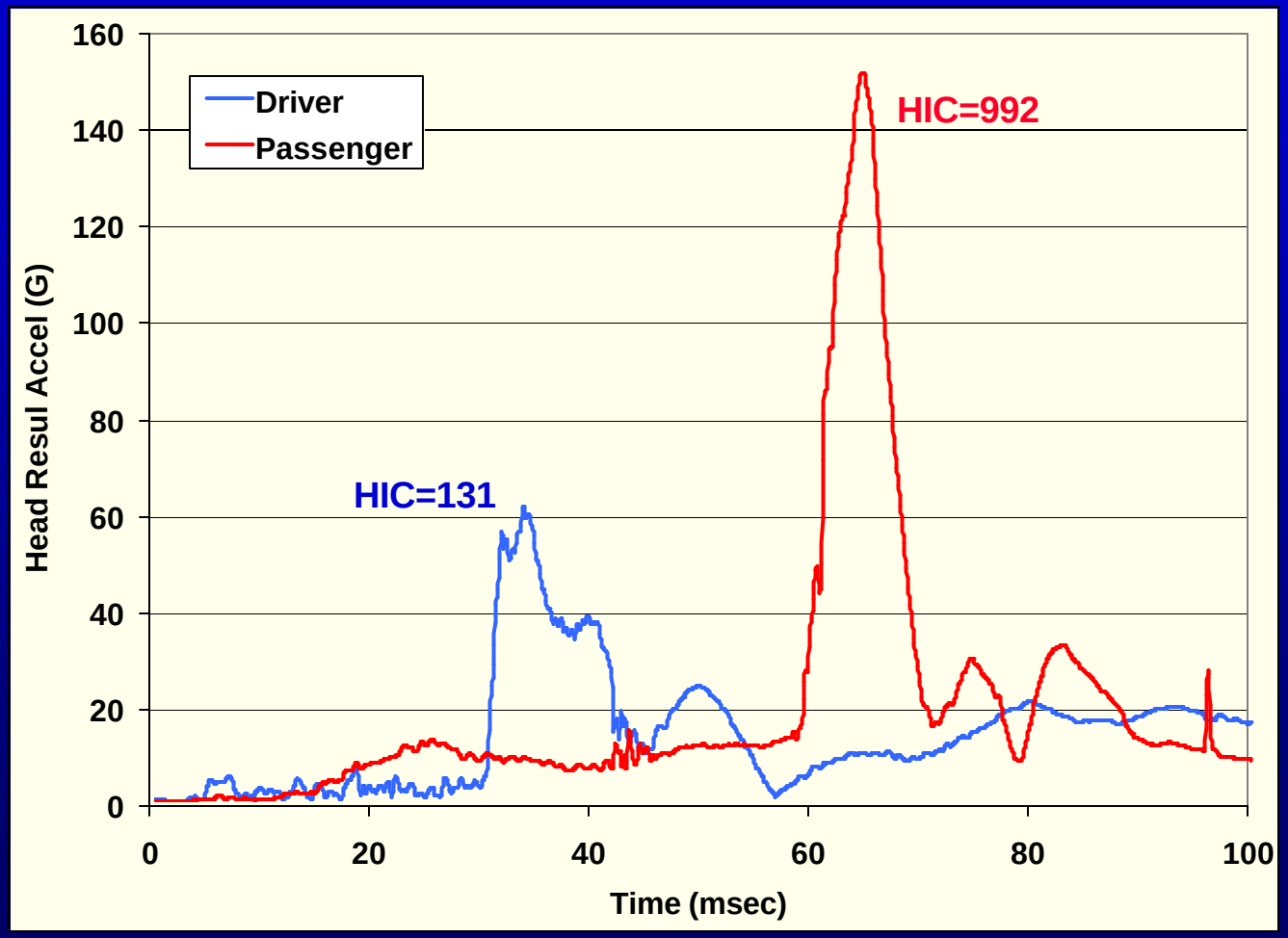
2002 Suzuki Vitara

Blue = face

Yellow = head vertex

Red = head rear

2002 Suzuki Vitara
Side NCAP Test



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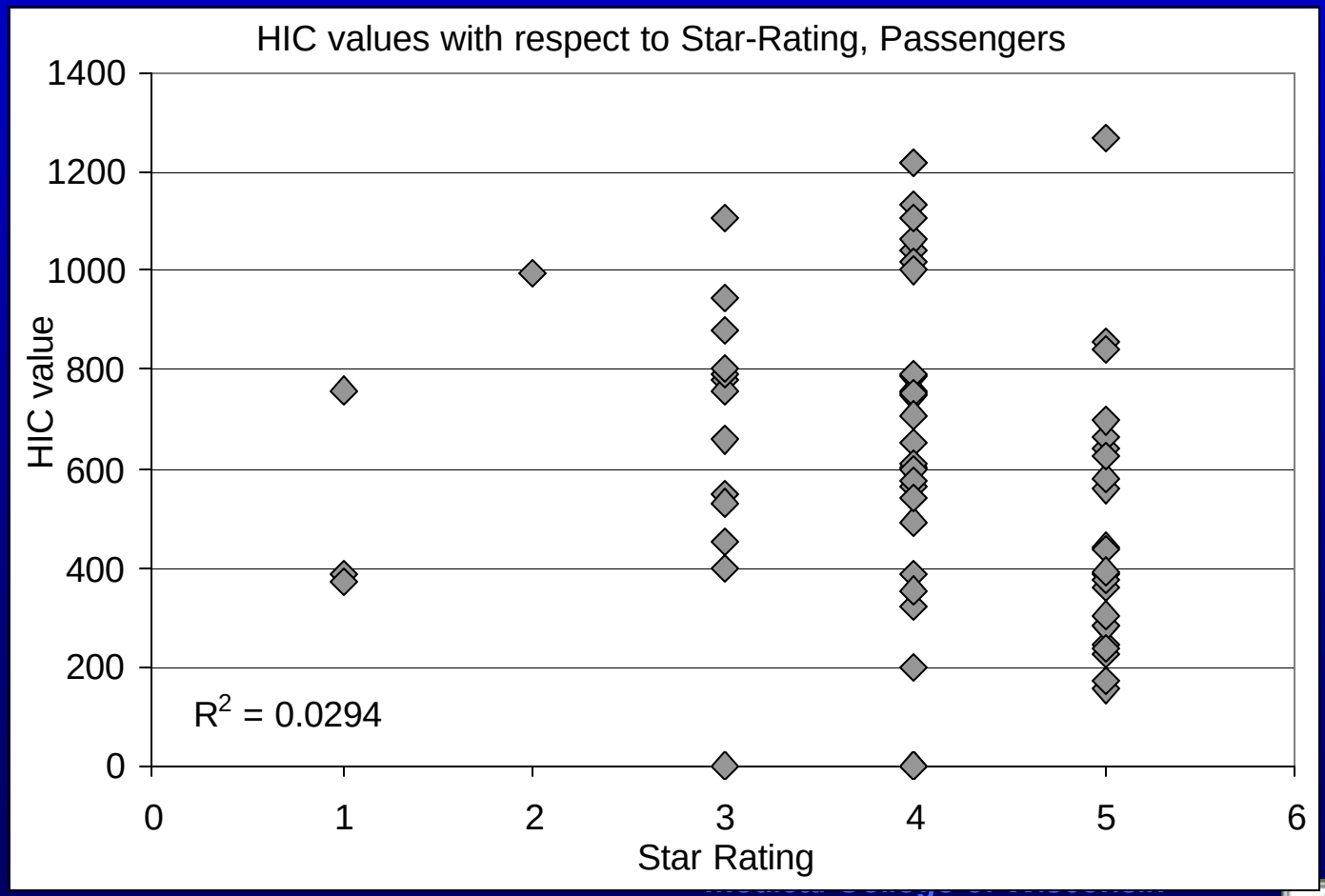
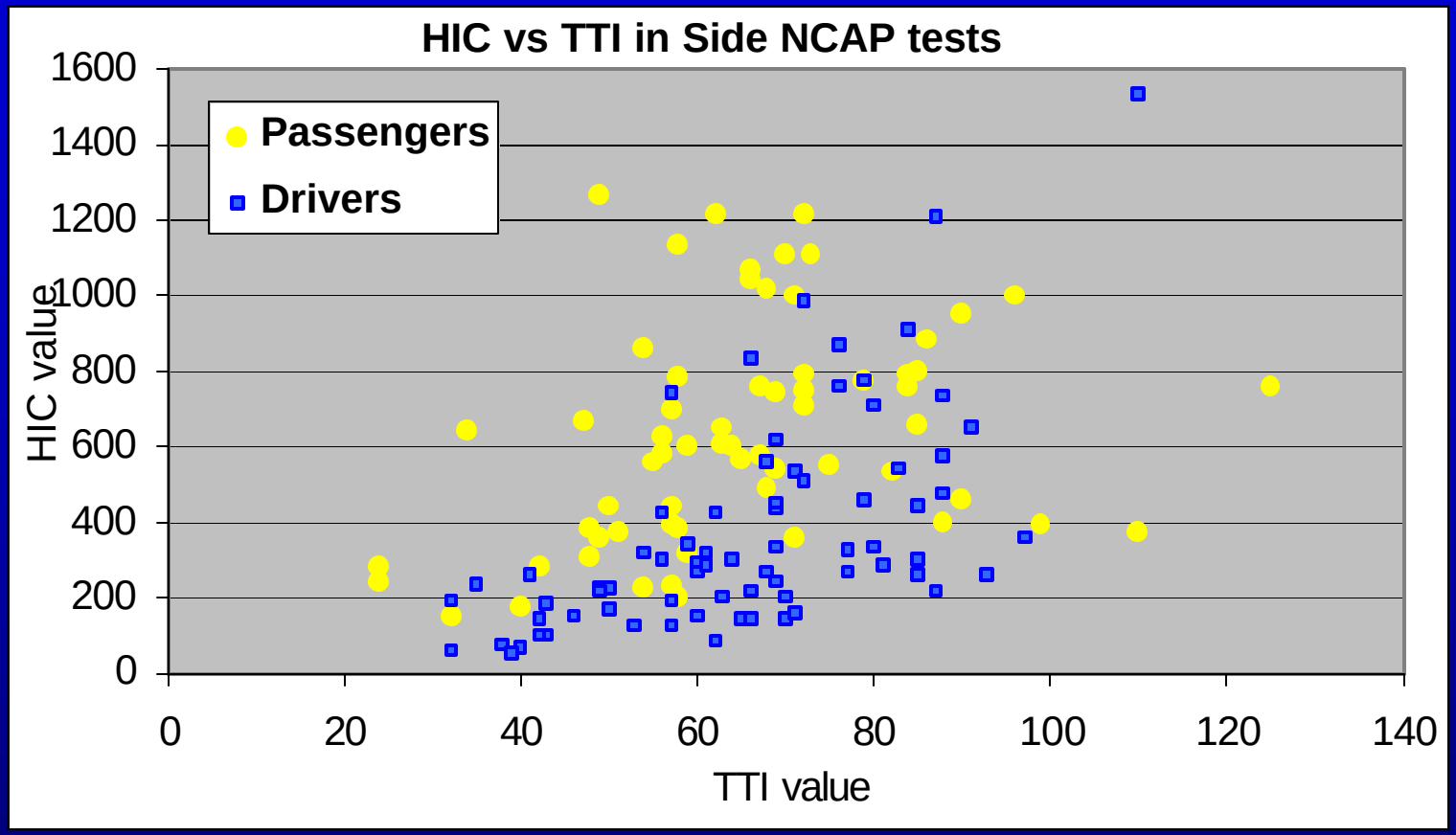
HIC and Star Rating correlate poorly



NCAP results: HIC



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2002 Ford T-bird NCAP Test Results; MCW

Actual Recorded Values vs Measured deformations Modeled as if it were a CIREN case

What does this mean for CIREN??

How many CIREN recons are like this?

Source	PDOF	Lateral	Longitudinal
Recorded ?V @ CG	270	27 kph	-8.5 kph
WinSMASH Barrier	270	13.7 kph	0 kph
WinSMASH Barrier	300	13.1 kph	-6.8 kph

Note: Impact speed more pertinent than delta V in side impacts

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Variability in Side NCAP

- Side wall construction
- Seating position (front or rear)
- Side airbag
- Vehicle weight
- Vehicle height

Occult Injuries in near side NCAP Occupants

- TBI: especially to rear occupant
- Upper Extremity Injuries ?
- Neck Injuries: likely
- Chest Injuries: yes
  - ➔ Rib fractures
  - ➔ Internal injuries
- Abdominal injuries: yes
- Pelvis: yes
- Lower Extremity injuries: ?

Conclusions

- NCAP duplicates the type of side crash situation that produces most HI (frontward)
- NCAP does not replicate the side crash that produces the most severe HI (direct side)

Conclusions

- Despite NASS data that shows many HI's in lateral crashes, current lateral NCAP regulations do not have criteria to minimize head injuries
- NCAP uses only TTI for "star safety" despite poor correlation between TTI and head g's or HIC
- Many NCAP occupants have worrisome HIC's, especially rear seat occupants.
- C pillar head strikes occur with "acceptible" TTI's
- Neck may be close to tolerance and needs further study
- Side impact criteria for injury need to be developed…soon!

What are some reasons for injuries to NCAP occupants?

- Variability in driver and passenger responses
- Poor relation between the injury criteria (TTI) and other injury tolerances (HIC)
- Many injuries not measured or accounted for (neck, abdomen, pelvis)
- High injury acceptance rate

Conclusion: for Side NCAP

- The “star” rating does not guarantee safety with regard to many injuries
- Injuries to NCAP occupants are occult!